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Hybrid Heat Pump Solutions for Industrial Energy Savings

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Hybrid Heat Pump Solutions for Industrial Energy Savings

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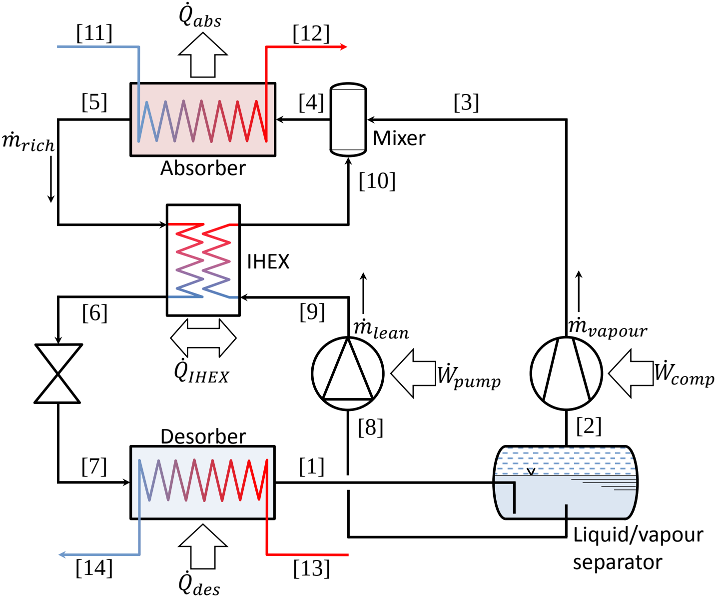
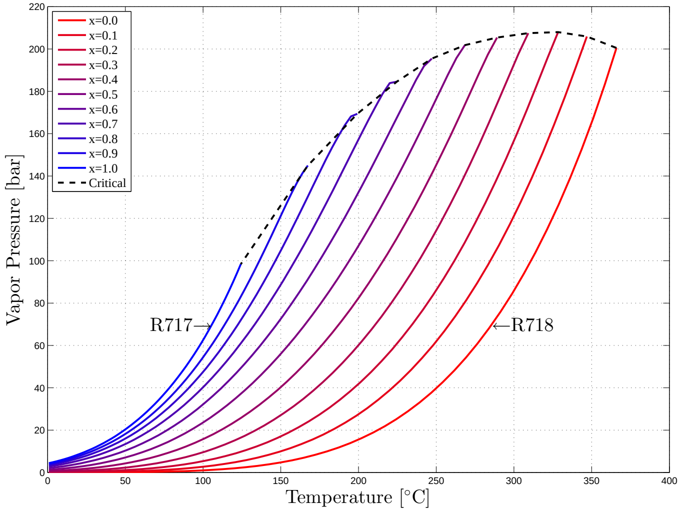
Agenda

- Introduction to the hybrid absorption compression heat pump
- Advantages of zeotropic mixtures specifically NH_3/H_2O
- Evaluation of important design parameters.
- Prospect for high temperature development T_{supply} <110°C.
- Conclusion & future work

The Hybrid Heat Pump



Advantages of Zeotropic Mixtures
Reduction of Vapor Pressure



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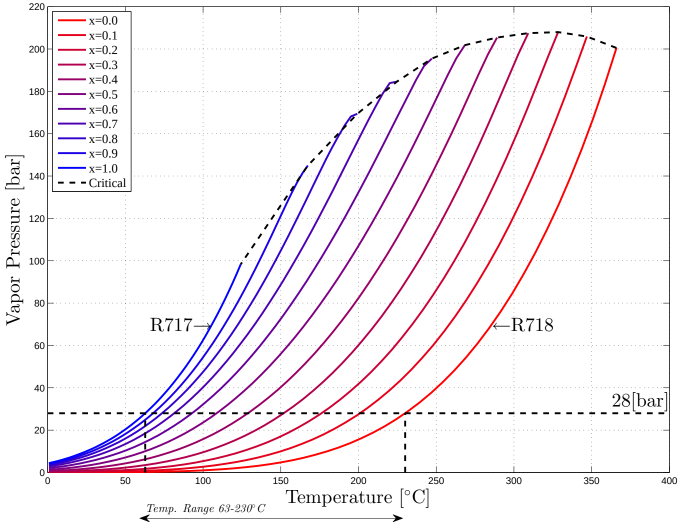

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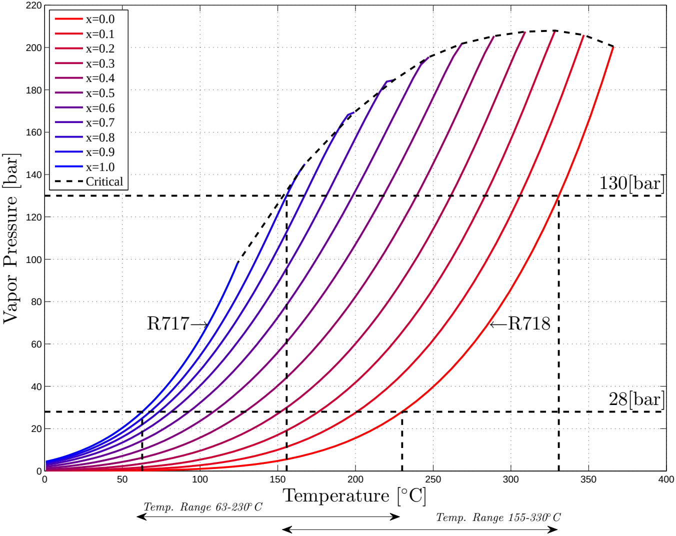
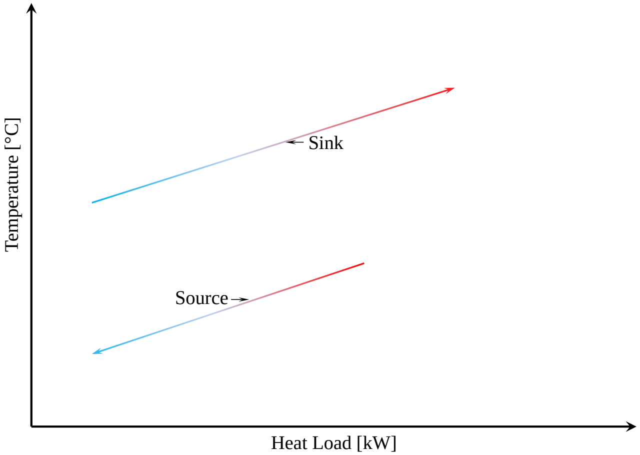


Advantages of Zeotropic Mixtures
Reduction of Entropy Generation



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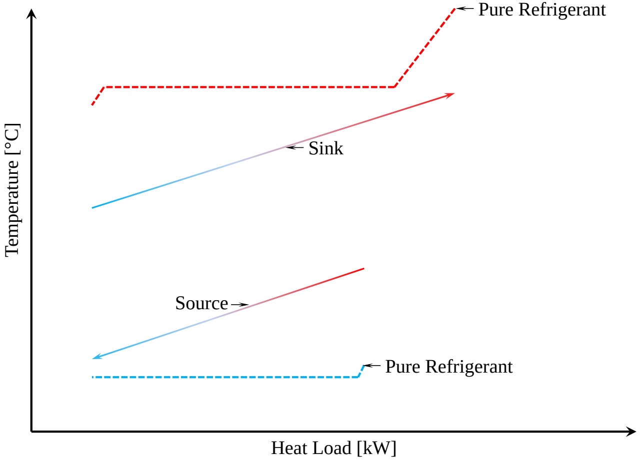

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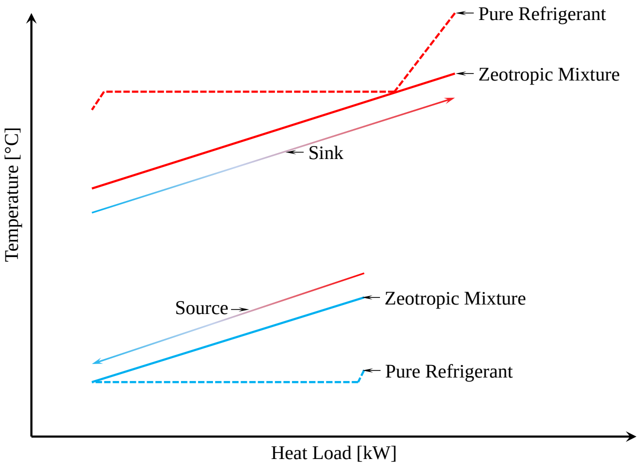

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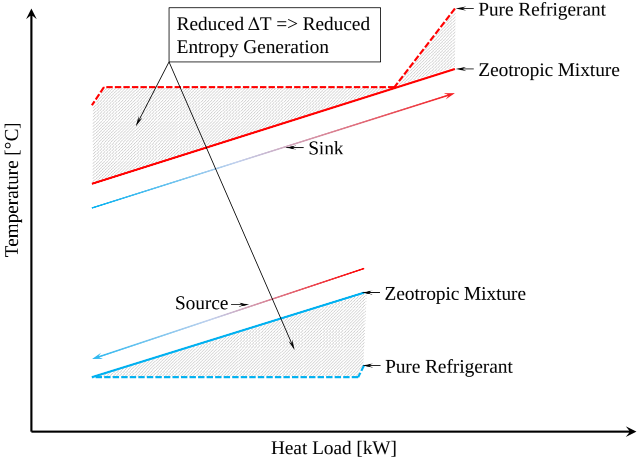

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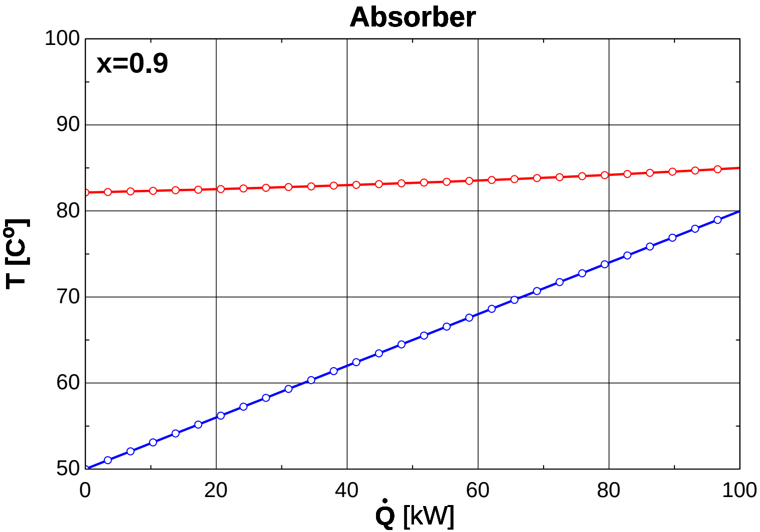

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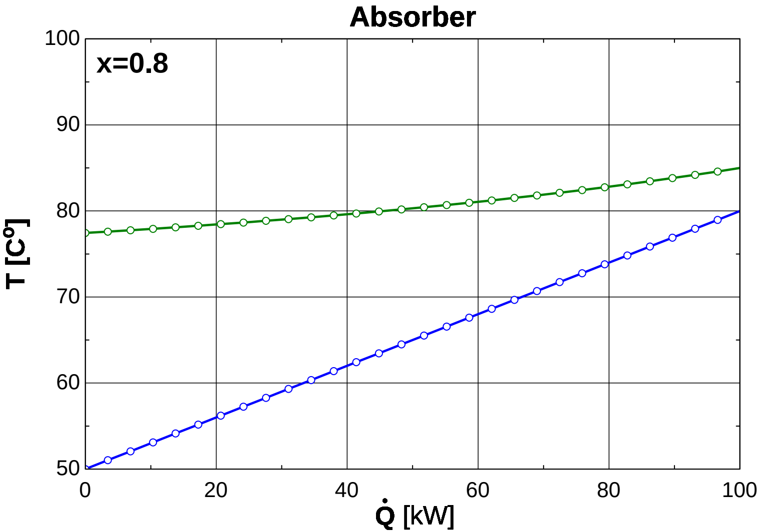

Advantages of Zeotropic Mixtures

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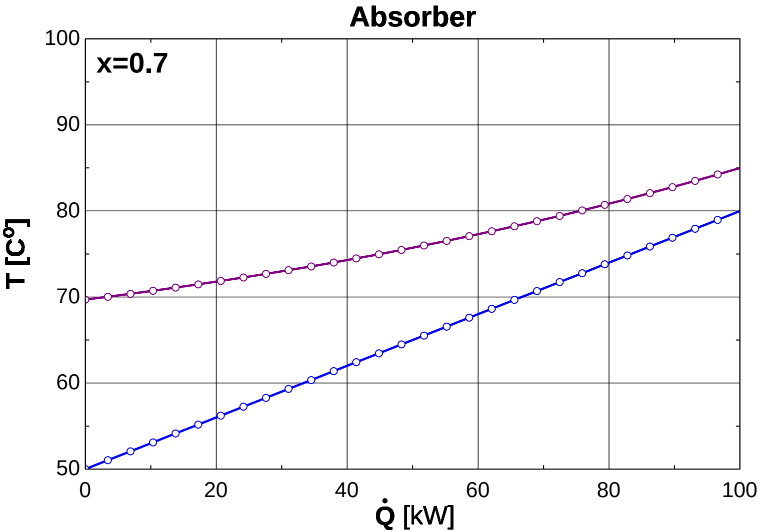

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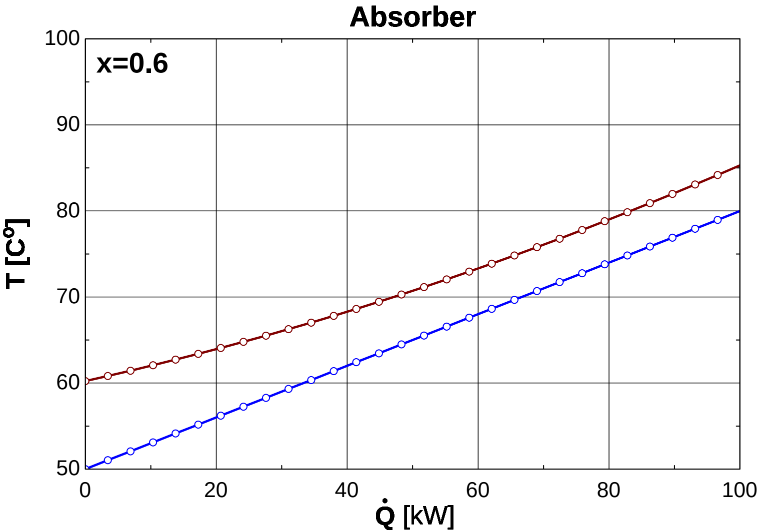

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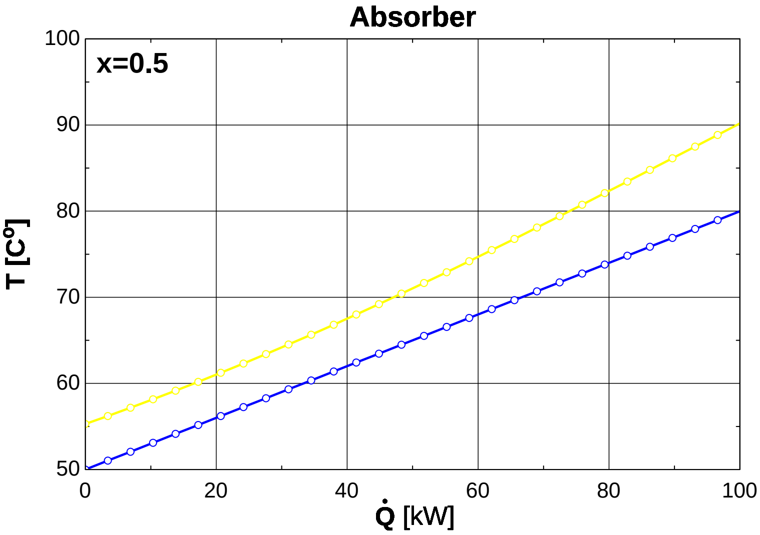

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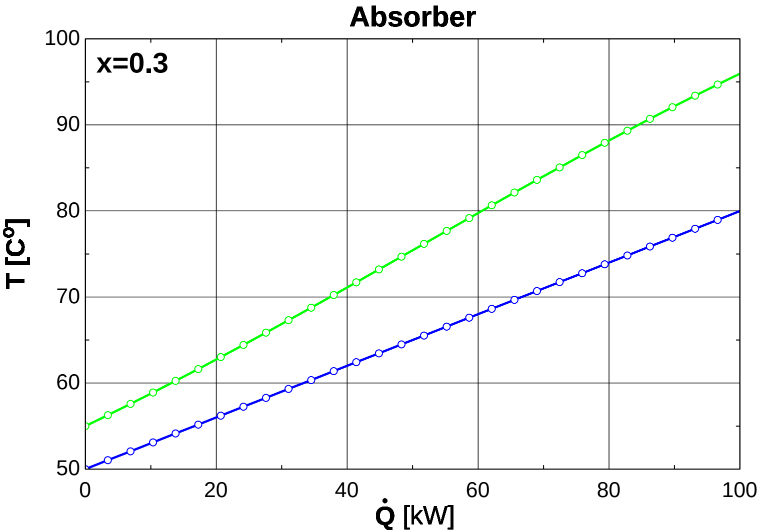

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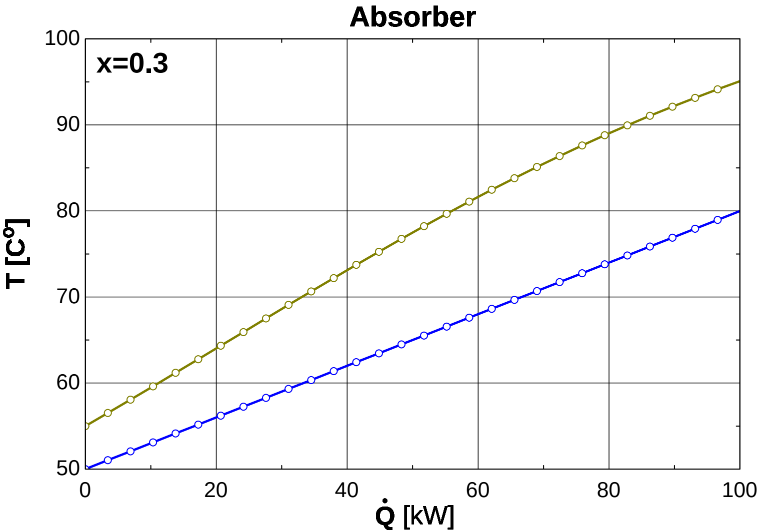

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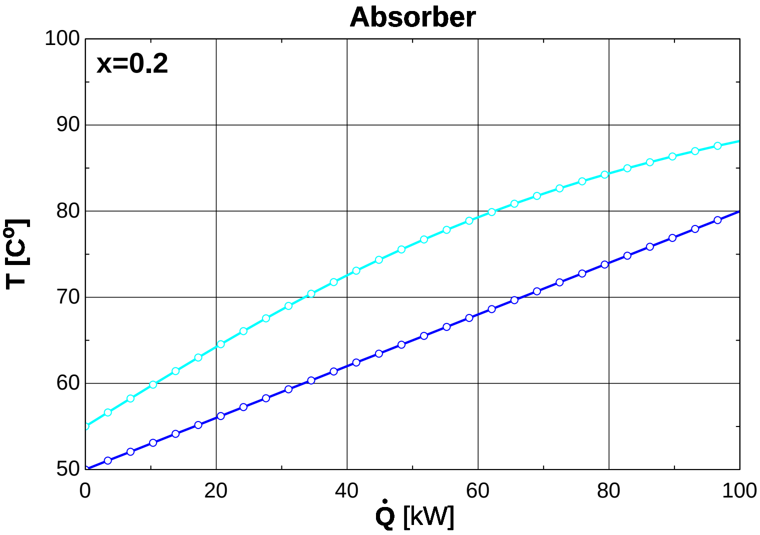

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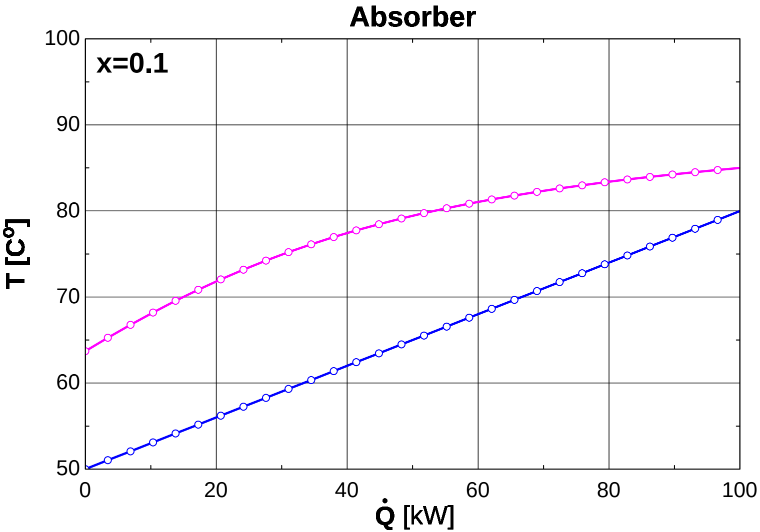
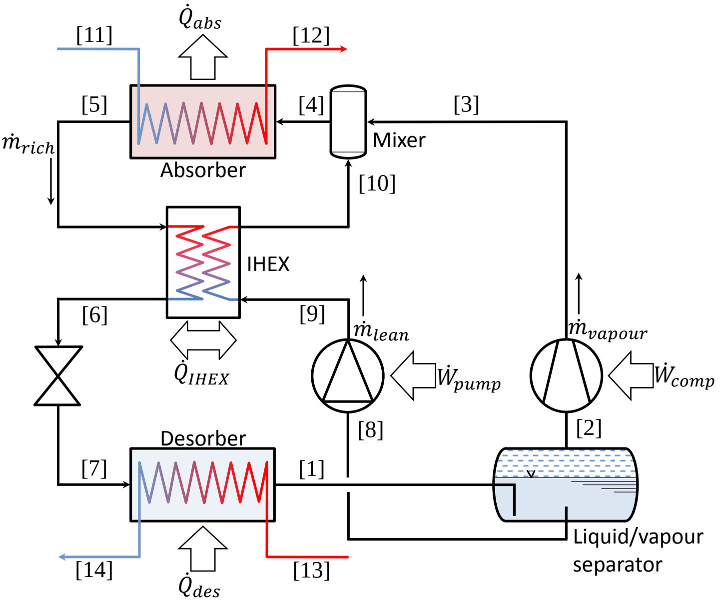


The Hybrid Heat Pump: Design parameters x_r & f



Influence of x_r & f: $T_{sink,out} = 110°C$, $\Delta T_{lift} = 30°C$

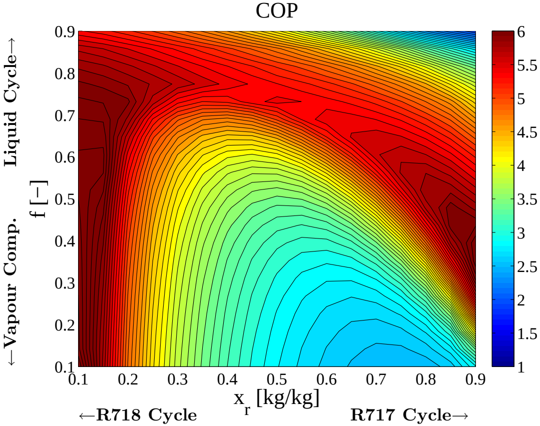
Inputs and Assumptions

External Inputs	
$T_{sink,in} =$	80°C
$T_{sink,out} =$	110°C
$T_{source,in} =$	80°C
$\dot{m}_{sink} =$	1kg/s
$\dot{m}_{source} =$	10kg/s

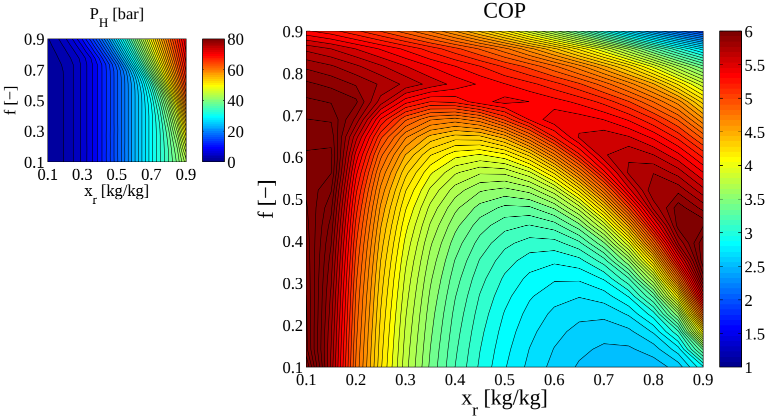
Internal Inputs	
$\Delta T_{pinch,abs} =$	5°C
$\Delta T_{pinch,des} =$	5°C
$\eta_{is,comp} =$	0.7
$\eta_{is,pump} =$	0.7
ϵ_{IHEX}	0.8

Pressure drops are neglected.

Influence of x_r & f: $T_{sink,out} = 110°C$, $\Delta T_{lift} = 30°C$



Influence of x_r & f: $T_{sink,out} = 110°C$, $\Delta T_{lift} = 30°C$



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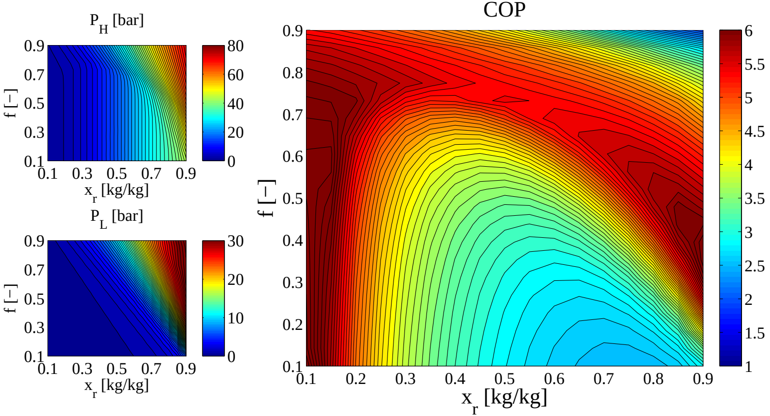
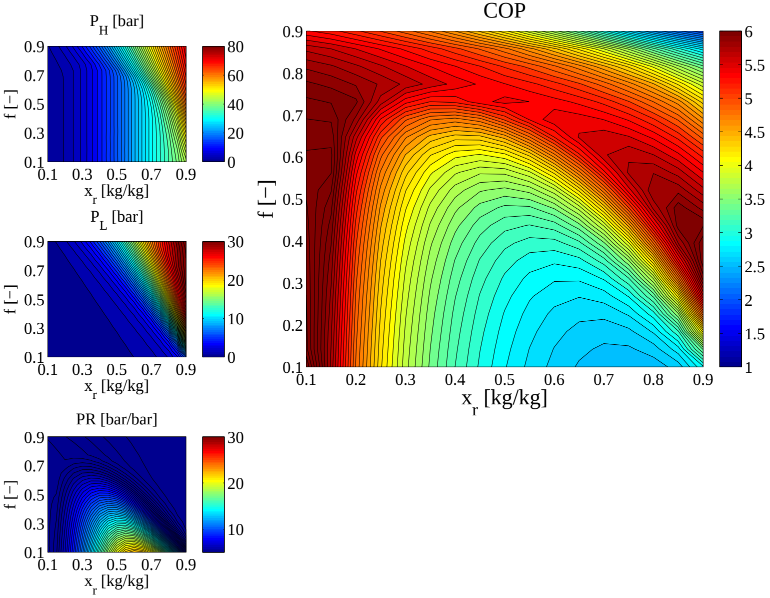
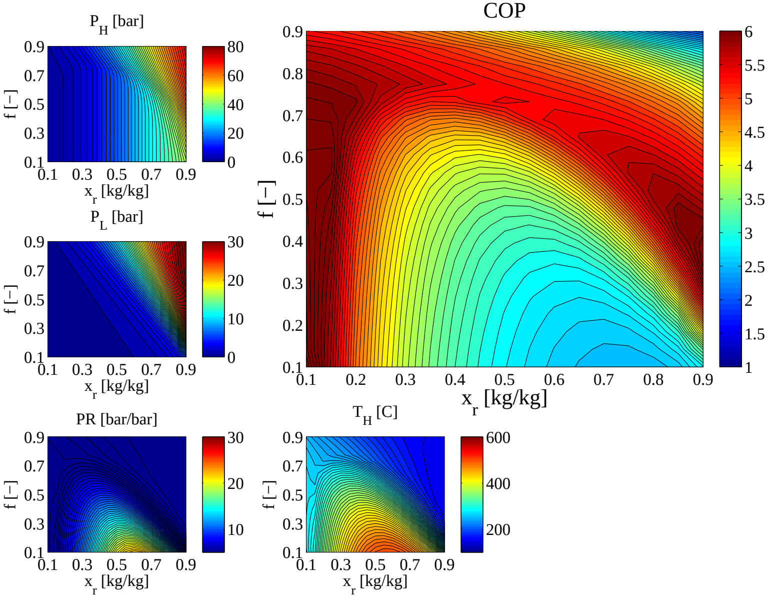


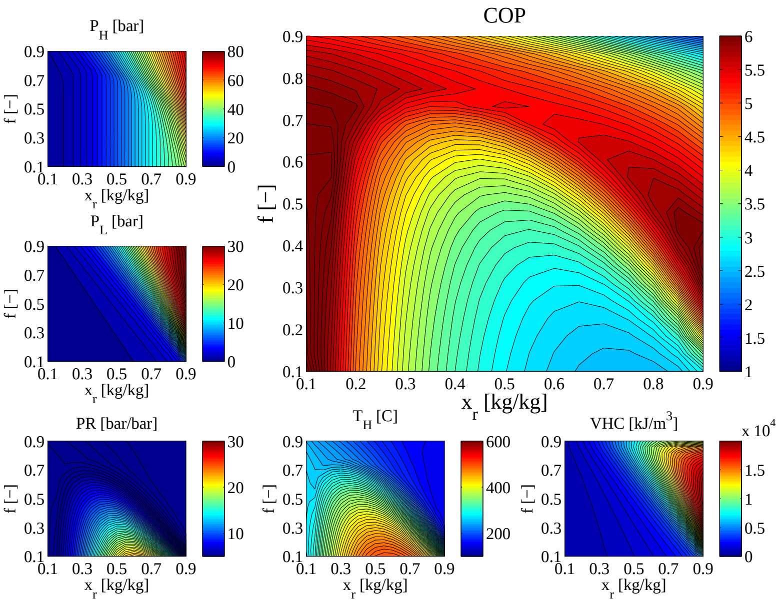
Influence of x_r & f: $T_{sink,out} = 110°C$, $\Delta T_{lift} = 30°C$



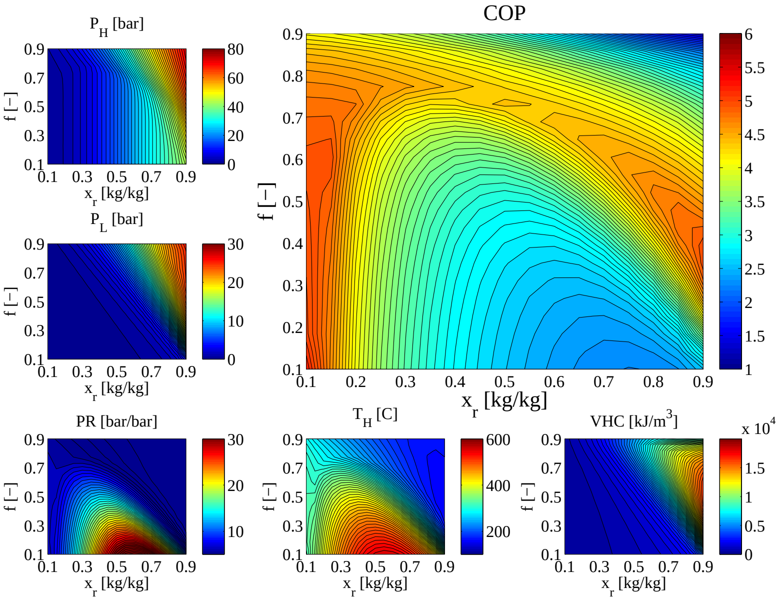
Influence of x_r & f: $T_{sink,out} = 110°C$, $\Delta T_{lift} = 30°C$



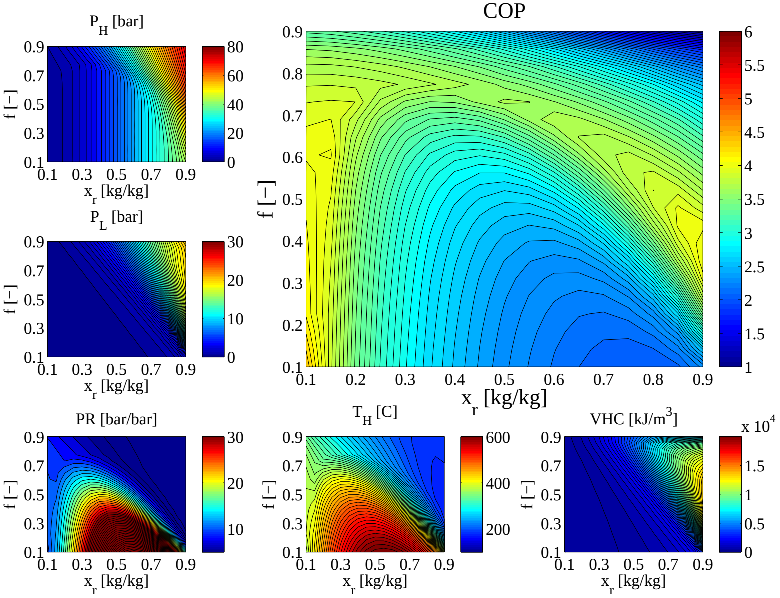
Influence of x_r & f: $T_{sink,out} = 110°C$, $\Delta T_{lift} = 30°C$



Influence of x_r & f: $T_{sink,out} = 110°C$, $\Delta T_{lift} = 40°C$



Influence of x_r & f: $T_{sink,out} = 110°C$, $\Delta T_{lift} = 50°C$

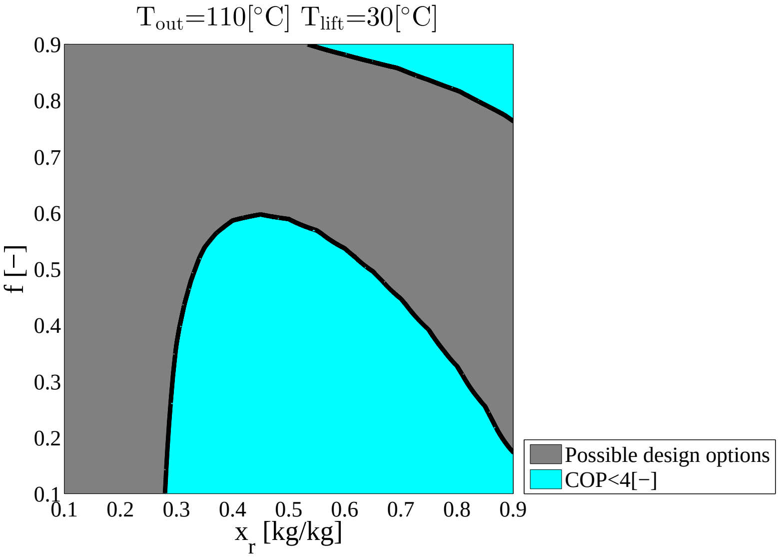


Working domain hybrid heat pumps

Constraints corresponding to standard refrigeration components

Design Constraints		
COP	$> 4[-]$	Economic
P_H	$< 25[bar]$	Standard refrigeration equipment
P_L	$> 1[bar]$	No entrainment of air from ambient
VHC	$> 2[MJ/m^3]$	Economic ($\dot{Q}_{abs}/\dot{V}_{suc,comp}$)
T_H	$< 160[°C]$	Thermal stability of oil

Working domain hybrid heat pumps



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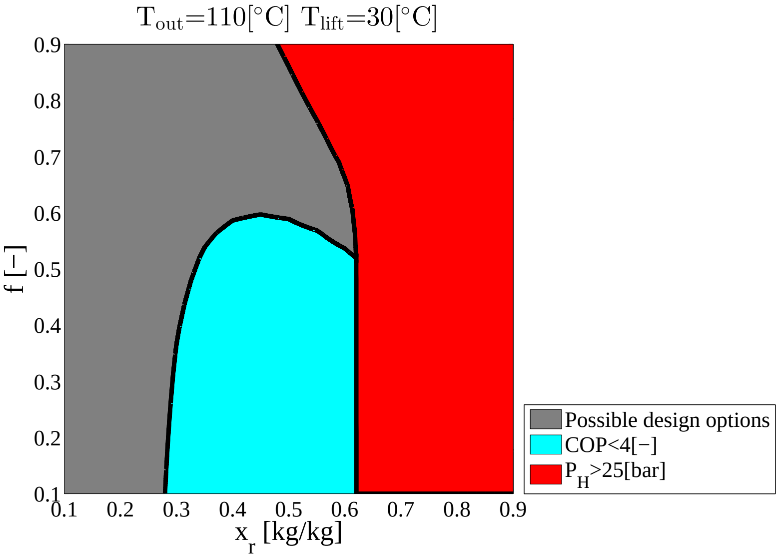

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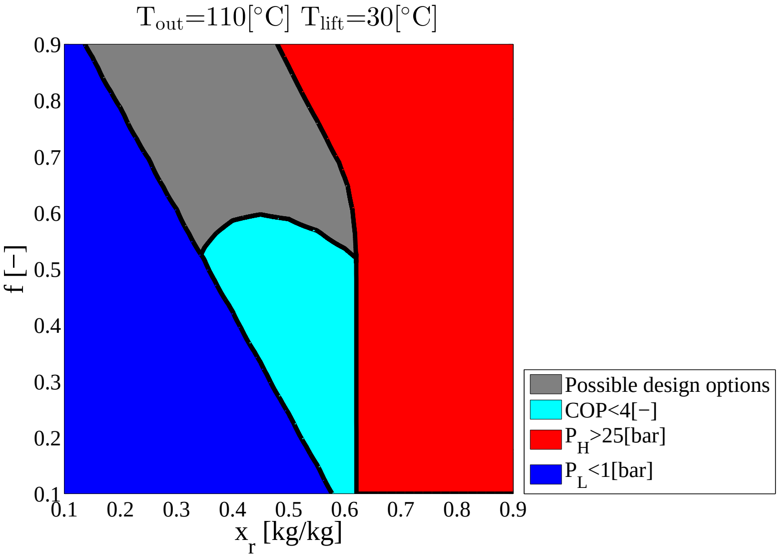

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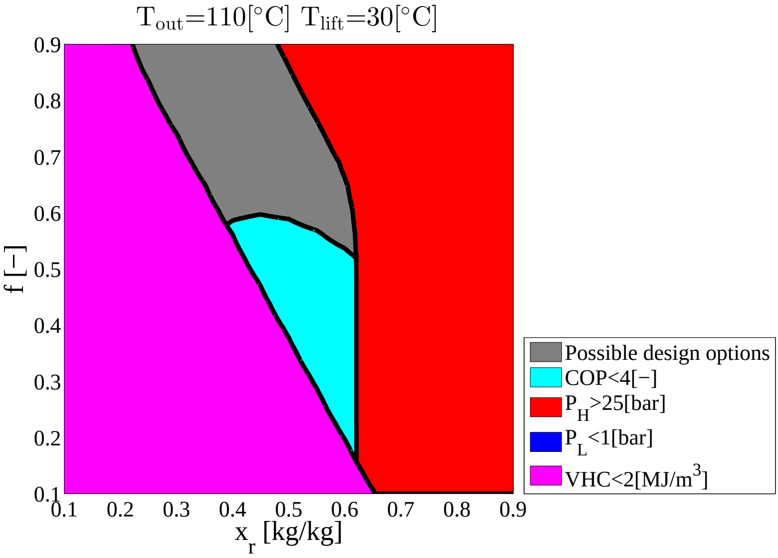

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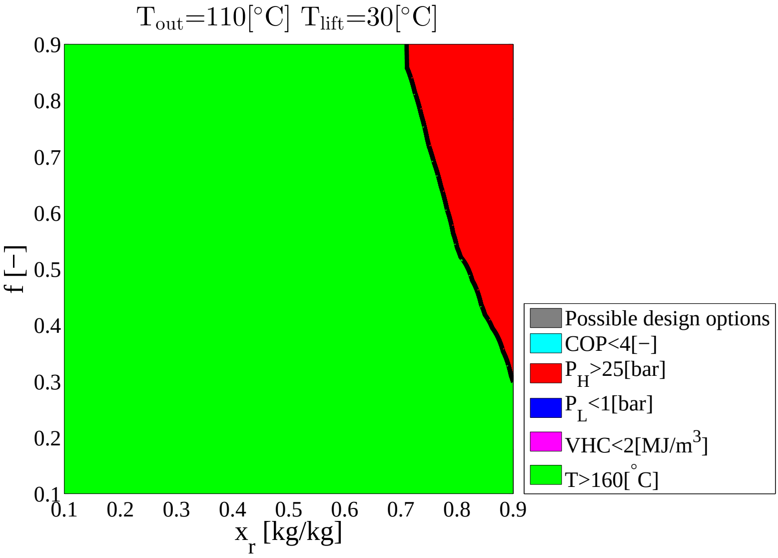
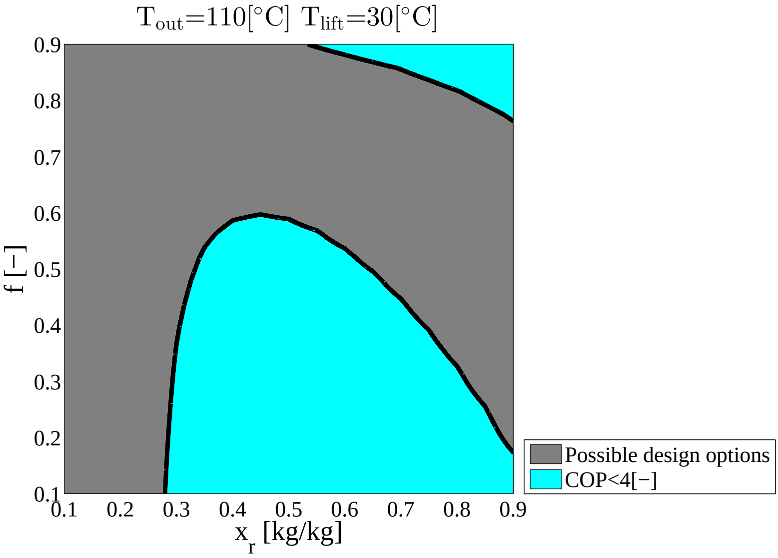


Working domain hybrid heat pumps

Constraints corresponding to supercritical CO_2 refrigeration components and new synthetic oils

Design Constraints		
COP	$> 4[-]$	Economic
P_H	$< 130[bar]$	Standard refrigeration equipment
P_L	$> 1[bar]$	No entrainment of air from ambient
VHC	$> 4[MJ/m^3]$	Economic ($\dot{Q}_{abs}/\dot{V}_{suc,comp}$)
T_H	$< 250[°C]$	Thermal stability of oil

Working domain hybrid heat pumps



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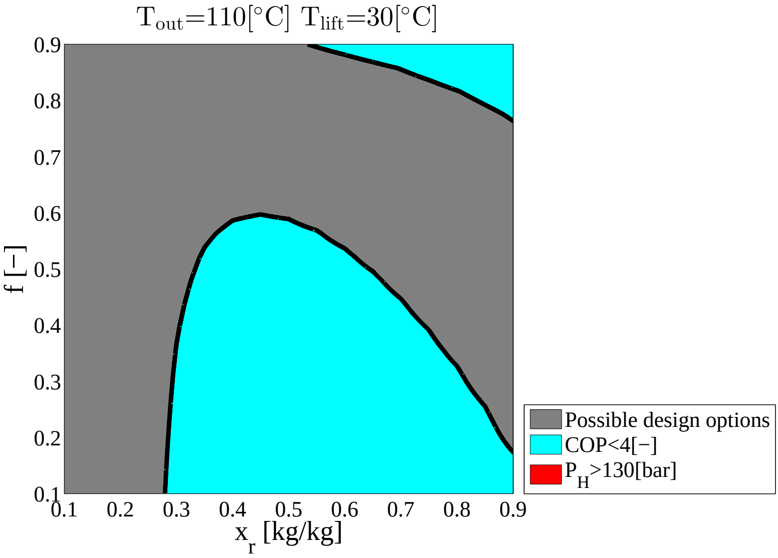

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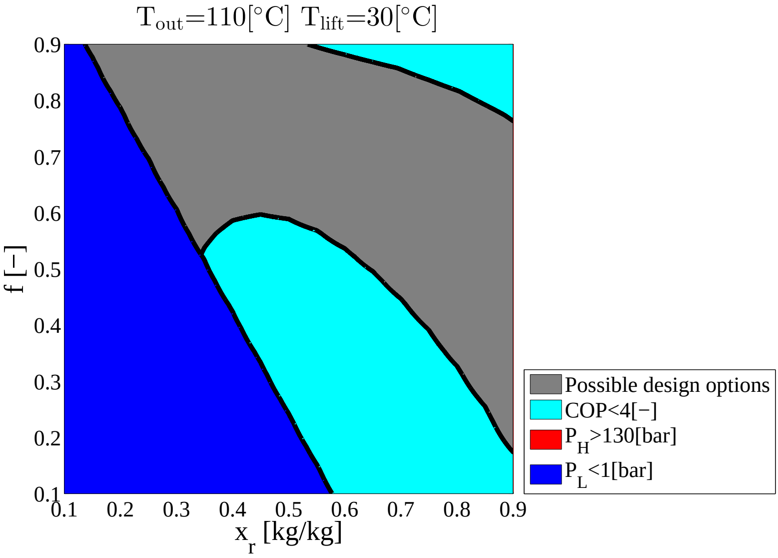

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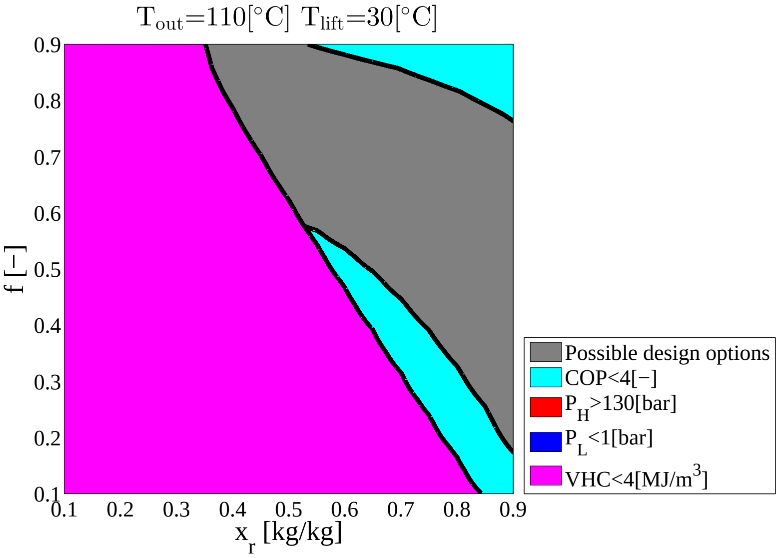

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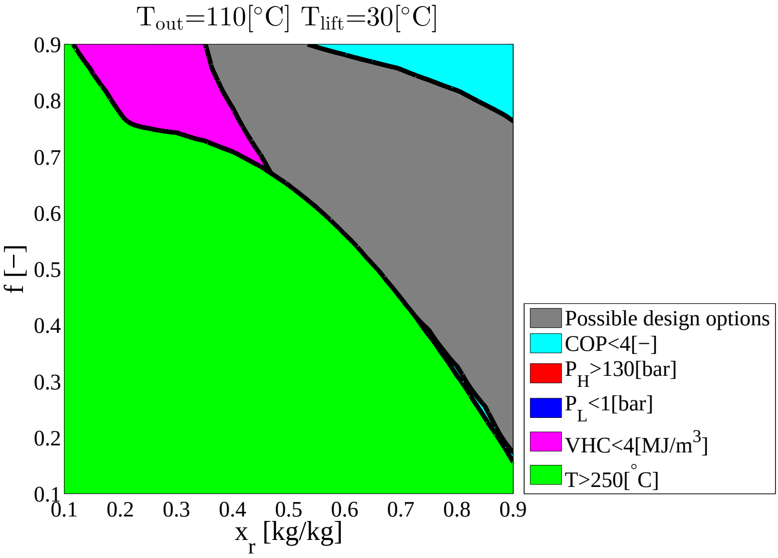
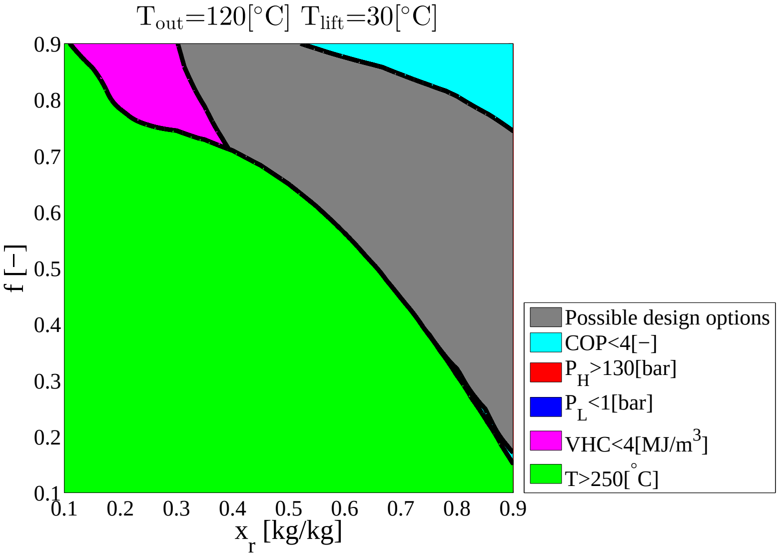


Working domain hybrid heat pumps: $T_{sink,out}$



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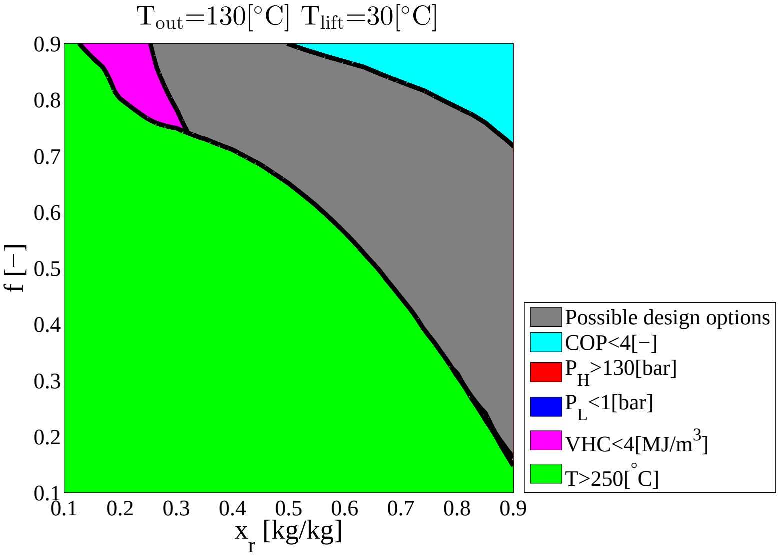

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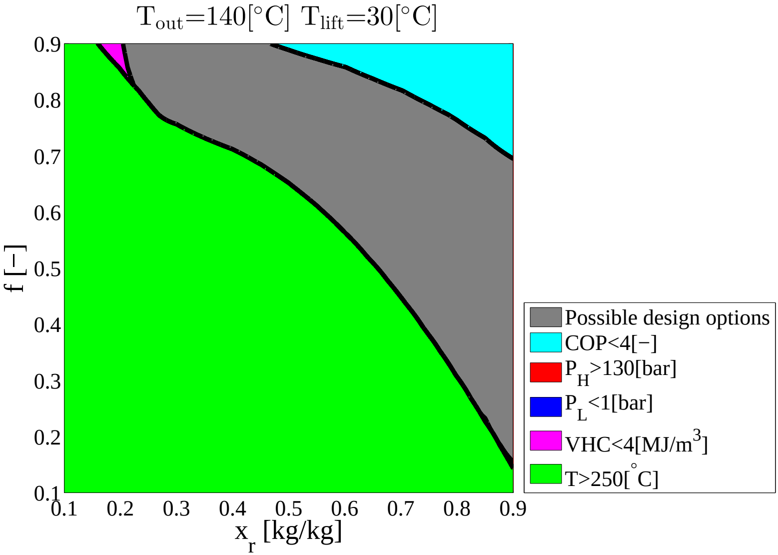

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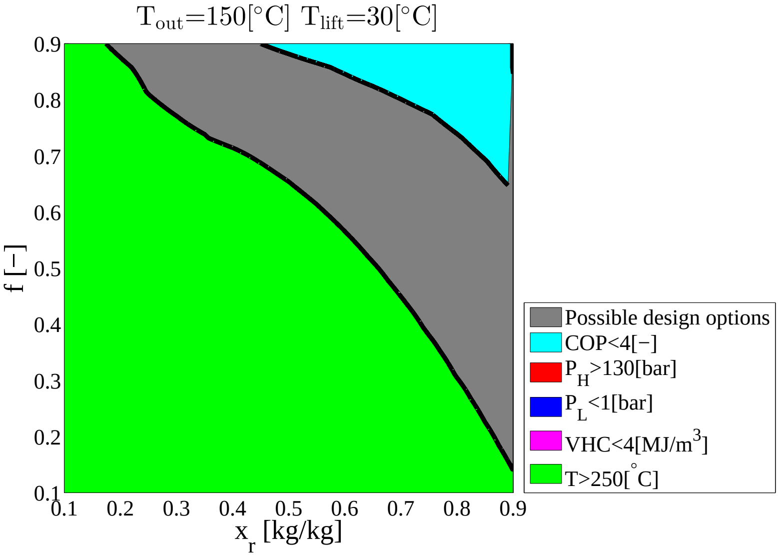

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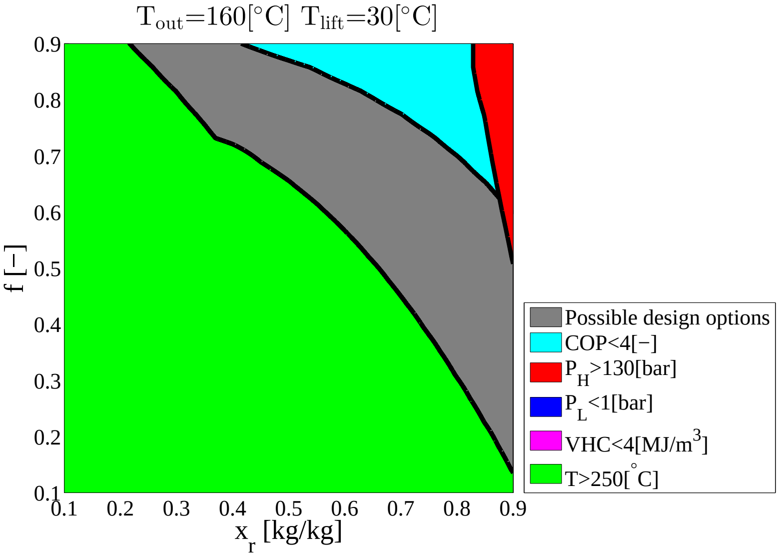

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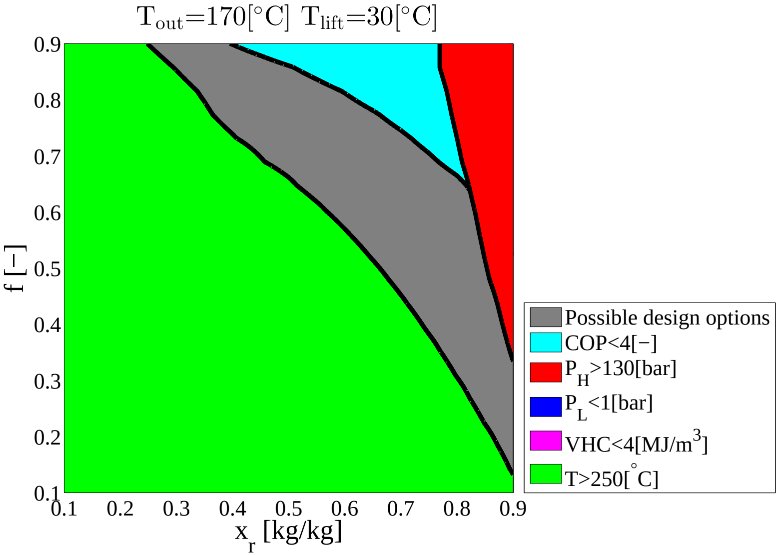

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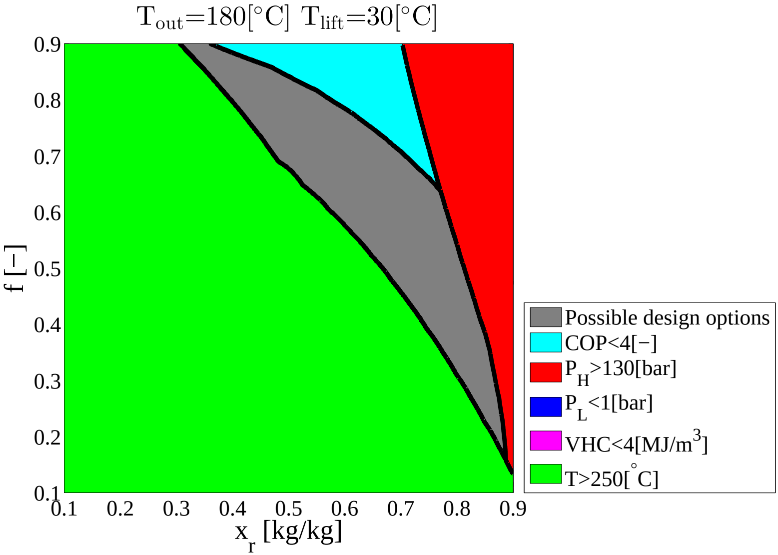

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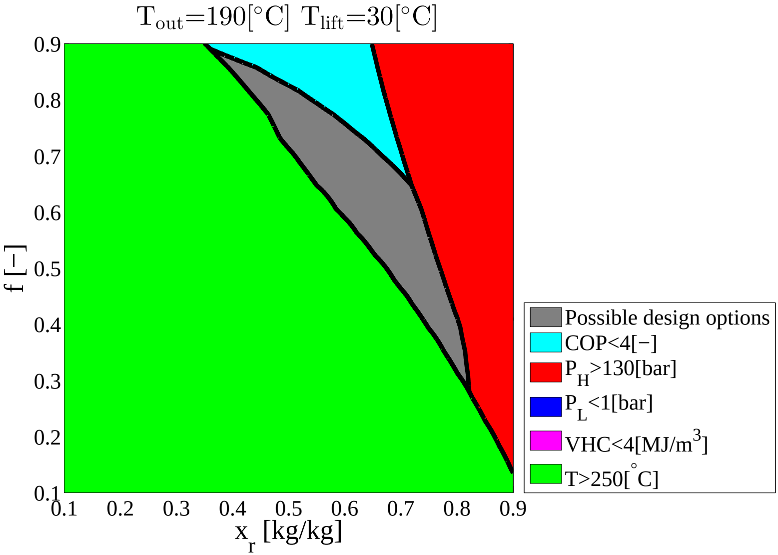

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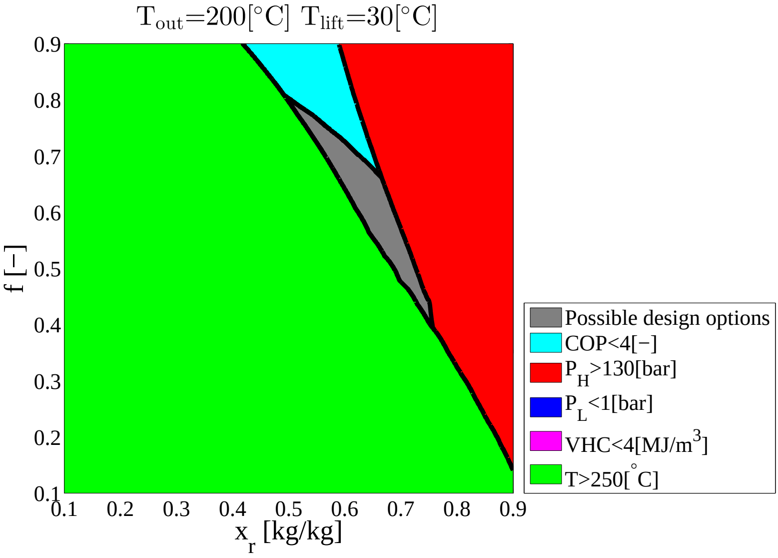
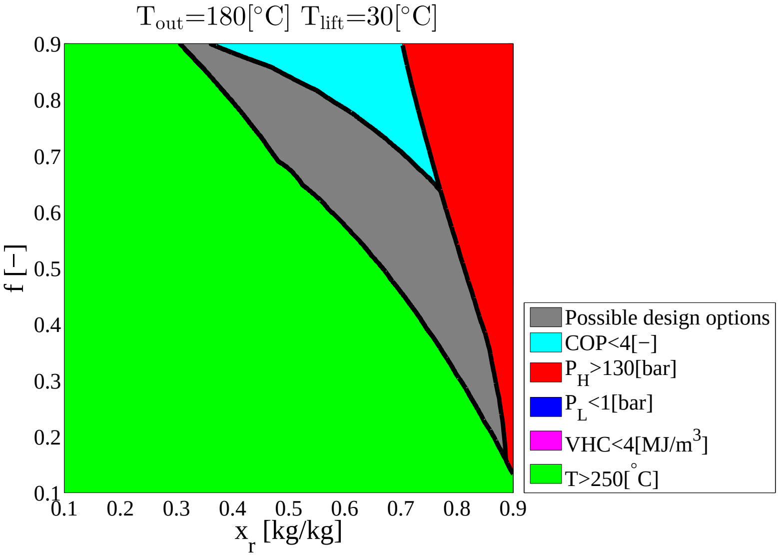


Working domain hybrid heat pumps: ΔT_{lift}



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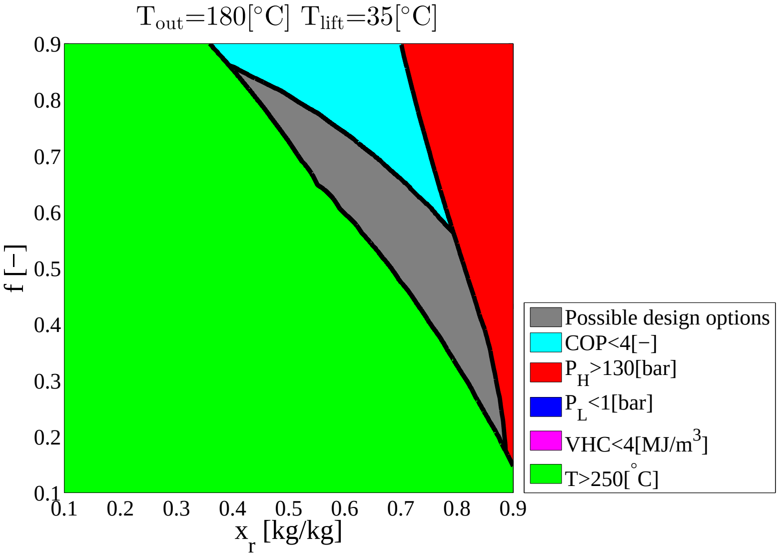

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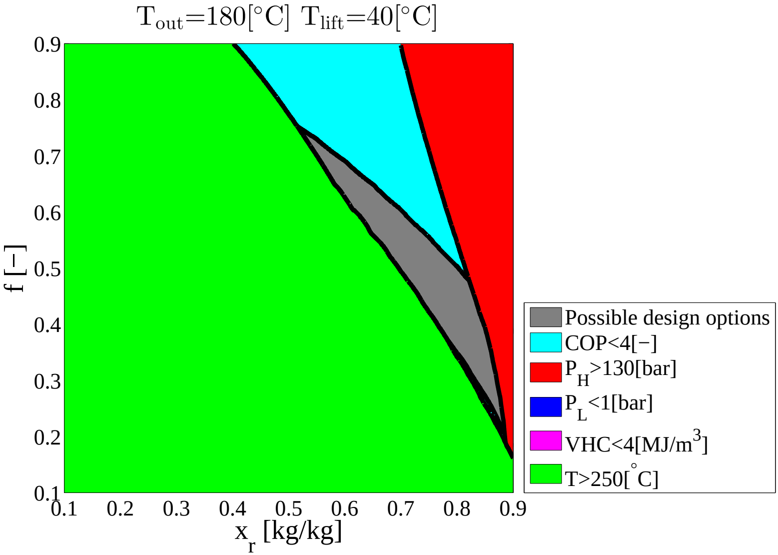

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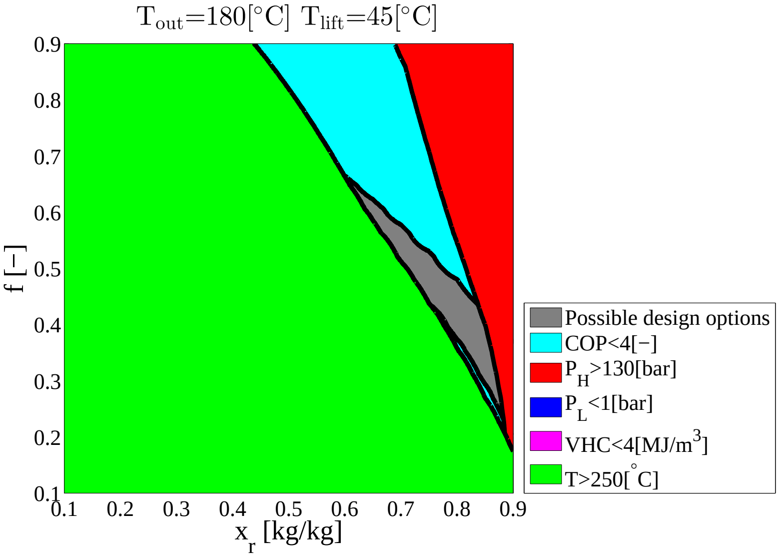

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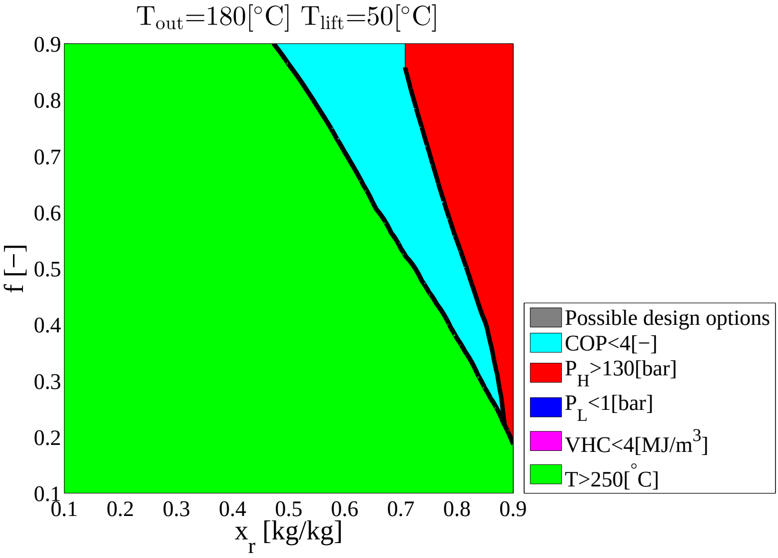
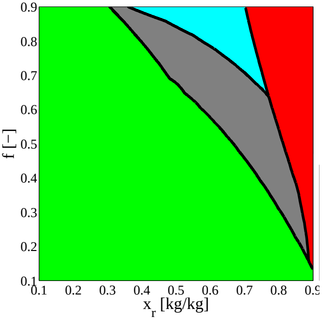


Future work

- Heat transfer characteristics, influence of x_r.
- Identification of suitable oils.
- Material compatibility with NH_3/H_2O should be investigated
- Two-stage concepts should be evaluated, this could reduce compressor discharge temperature and increase COP.
- Thermoeconomic analysis and optimization should be applied to find cost efficient designs.



Conclusion

- COP and design parameters are highly dependent on x_r and f.
- Standard refrigeration components can be used upto 110[$^\circ$C].
- Supercritical CO_2 components can be used upto 200[$^\circ$C].
- ΔT_{lift} upto 45[$^\circ$C] can be attained.
- Dominating constraint is the compressor discharge temperature.
- Hence thermal stability of oil should be tested.
- Case studies should be performed to show the feasibility of the hybrid heat pump implementation.

Thank you for your attention.
Questions?